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A Pilot Study on the Feasibility of Establishing Willow Energy Plantations in Newfoundland

by

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A PILOT STUDY ON THE FEASIBILITY OF ESTABLISHING WILLOW ENERGY PLANTATIONS IN NEWFOUNDLAND

(ENFOR PROJECT P-172)

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1. INTRODUCTION

Accelerating costs, increasing demand, and diminshing supplies of non-renewable energy sources are making the growing of wood for fuel purposes particularly attractive. Interest in the concept of short rotation forestry began in the 1960's as a potentially efficient and inexpensive method of producing wood biomass. In more recent years the approach has been considered as an alternative energy source. Used interchangeably in this report, the terms energy plantation, energy farm, and energy forest refer to willows planted at high densities, managed to optimize biomass production, and coppiced every two or three years for use as fuelwood.[1]

European experience has shown the genus Salix, with its wide ecological amplitude and fast-growing characteristics, to be a promising energy crop particularly suited to boreal forest regions. Trials conducted in Newfoundland have indicated that it is feasible to obtain yields of 8-11 oven dried tonnes/ha/yr with certain willow clones on a 2-3 year rotation (Robertson 1981).

The establishment of energy plantations using fast-growing Salix species in Newfoundland could play an important role by reducing fuel oil consumption, creating rural employment, and by putting into production land that is presently underutilized.

The intent of this study was to undertake a preliminary examination of the environmental, technical, and economic feasibility of establishing such plantations in Newfoundland.

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[1] This system refers to osier-type coppices, i.e. a 2-3 rotation period, whereas tree-type coppices are for rotations of 5-10 years.

1.1 Project Objectives

The project was designed with the following objectives:

a. The development of land suitability criteria and the preparation of maps of a study area for which suitable areas for *Salix* energy plantations can be determined.

b. Conduct a fuel consumption study of some potential markets to determine fuelwood equivalence and energy plantation land area requirements.

c. Assess the economic feasibility of energy plantations.

d. Collect information on all aspects of energy plantation research and development.

e. Conduct a biogeographical study of native willows in Newfoundland involving the collection of specimens.

The following section is a brief review of fuelwood consumption trends and some programs that have been initiated to stimulate use of this alternative energy source. Part three involves determining criteria for land suitable for energy plantations. A case study of the Cochrane Pond - Bay Bulls Big Pond area comprises the fourth section of the report. Part five looks at the fuel consumption of selected schools and hospitals, seen as potential markets for energy farms, across the Province. An evaluation of the costs and projected revenues of a willow energy plantation is made in part six. The final section deals with the field work done in April 1982 to collect specimens of native willows.

2. FUELWOOD CONSUMPTION AND PROGRAMS IN NEWFOUNDLAND

The following is an overview of current fuelwood consumption and alternate fuel programs in progress in the Province. A general outline of these trends and programs is helpful in determining the demand and potential markets for an energy farm industry. Various reports were consulted and government agencies and individuals contacted to ascertain the demand and source of fuelwood and the alternate fuel programs in effect in insular Newfoundland.

Domestic Use:

An ENFOR report on domestic fuelwood consumption indicated that the number of homes burning wood for heating purposes increased from 22,000 in 1973 to about 39,500 in 1978 (Northland Assoc. n.d.). The highest volume of fuelwood consumed on the Island is on the Avalon Peninsula at an estimated 110 400 stacked m^3 (30,459 cords) (Northland Assoc. n.d.). In the three eastern regions (Avalon, Burin, and Bonavista peninsulas), the cutting of wood for domestic fuel use accounted for 31-77% of the annual allowable cut. A recent report of the Royal Commission on Forest Protection and Management (1981) has, however, identified the problem of unauthorized domestic cutting for fuelwood and the ensuing destruction of prime immature stands. The report states that only a fraction of the people cutting on non-alienated Crown Lands actually apply for a permit. The report thus claims that estimates of wood harvested for fuelwood are not reliable.

Remarks:

The trend of increasing use of wood for fuel in Newfoundland will no doubt continue as oil and electricity pricescontinue to escalate. Energy plantations could play an important part in supplying wood for that increased demand. In the more densely populated eastern region, in particular, energy farms appear practical and would also create needed employment. A local supply of fuelwood may help diminish unauthorized domestic cutting and the detrimental consequences.

Newsprint Mills:

Both Abitibi-Price (Grand Falls) and Bowater (Corner Brook) have conducted trial programs of utilizing forest biomass as an alternate source of fuel. The source of wood has been non-commercial trees within a 3-20 km distance of the Abitibi-Price mill and a 45 km distance from the Bowater mill. Results from the 1979 Abitibi-Price trials have indicated savings of 15 and 32% at two sites when burning wood compared to the cost of burning the equivalent amount of oil (Wilton and Duffett 1980). A preliminary report on the Bowater trials show encouraging results and further trials are proposed (Bowater 1982).

Remarks:

The Bowater report claims that a continuing supply of forest biomass is essential before the possibility of installing a new boiler, designed specifically to burn bark and forest biomass, could be realized. The concept of short-rotation energy forests fits in well with this need

for a continuing fuelwood supply. Minimizing transportation costs is an integral part of utilizing biomass for fuel. Energy plantations established at economic distances from the mills may compare favourably with wood obtained from noncommercial stands. For example, after nearby stands are harvested cutting would have to be done on sites further from the mill, thus increasing transportation costs or, in inaccessible stands, necessitating costly road building.

Government Alternative Fuel Programs:

(a) As part of a federal-provincial demonstration agreement the Provincial Department of Mines and Energy last year initiated a residential wood-heat conversion program across the Province. There are presently 30 households in the program.

(b) The Department of Mines and Energy is also developing a biomass infrastructure for the Bonavista Peninsula. The aim of the project is to convert the heating facilities of large buildings, such as fish plants, to burn wood (pers. comm. Alec Windsor, Department of Mines and Energy). The Department of Mines and Energy will provide funding for these projects and will contact contractors to supply the wood chips.

(c) The Provincial Department of Forest Resources and Lands together with the Department of Mines and Energy have initiated a wood heating program at the Gander Hospital. The system is scheduled to commence operation in early 1983.

The fuel requirements of the hospital are approximately 4,600 tons of green chips (Duffett n.d.). A wood chip supply and distribution network, to be set up by the Department of Forest Resources and Lands, will be the major fuel source for the hospital supplemented with residue from local sawmills.

(d) The Federal Department of Energy, Mines and Resources has initiated a Canada Oil Substitution Program (COSP). The program provides funds for conservation measures and oil substitution. In terms of the latter, funds are available to private households, small businesses, and institutional buildings, such as schools and hospitals, to replace an oil-fired heating system or to add a supplementary heating facility that will contribute 50% of the space heating or hot-water requirements of the building. In insular Newfoundland the energy sources that may be substituted for oil include wood (or other locally available solid fuels such as coal or peat) and active solar heat (Energy, Mines and Resources 1982).

Remarks:

Government funded programs may sway various consumer groups to switch to or supplement their heating requirements with wood. However, local supplies of fuelwood are still needed. For example, according to the Provincial Department of Mines and Energy, a proposal submitted by Woodland Nurseries to convert to fuelwood has presently been rejected as no local woodchip source is currently available (pers. comm. Alec Windsor).

3. SUITABILITY CRITERIA FOR SALIX ENERGY PLANTATIONS

Generally the first step in planning for large-scale energy plantations is the determination of available and suitable land. After these areas have been designated, further refinement is necessary to match selected species with selected sites. The scope of this study is concerned with the initial stage only, that is, in defining criteria of suitable land.

The principal categories involved in determining the availability of suitable land are outlined below:

Biological considerations	soil characteristics	soil texture soil depth drainage
	climate	precipitation length of growing season
	elevation	
Technical considerations	slope surface stoniness bedrock exposure	
	land use	present proposed
Socio-economic considerations	accessibility extent of suitable land hauling distance	

3.1 Biological Considerations

This category refers to those aspects that affect crop yield. Within this category the following criteria were chosen on the basis of recent literature findings.

- maximum elevation of 300-400 metres[1]
- annual precipitation at least 64 cm[2]
- imperfect to well-drained soils[3]
- fine to medium soil texture[4]
- length of growing season ⩾ 900 degree days[5]

Three to four hundred metres is suggested as the maximum altitude for growing energy forests in Sweden which in many respects has a climate similar to much of Newfoundland. Although the report does not specify conditions for growing Salix, lack of other information suggests this figure to be an adequate starting point.

Similar studies on the suitability of biomass farms in the United States assert that an annual precipitation of at least 64 cm is necessary. As Salo et al. (1977) point out, annual precipitation is only one aspect of moisture balance relationships. Distribution of precipitation is also an important consideration. An even distribution throughout the year is ideal.

Most willows grow naturally in moist soils. As Robertson (in preparation) points out, even some xerophytic species, such as the European Salix daphnoides, S. acutifolia, and S. xerophila, can tolerate moist sites. Fege (1981) suggests that while growth of willows is best on well-drained sites, the genus can generally tolerate soils that are periodically flooded including swamp land that is inundated for up to three months of the year. Trials in northern Ireland have shown that three Salix taxa (S. alba, S. viminalis, and S. x aquatica 'GIGANTEA') are tolerant of high water tables; the clone S. x aquatica 'GIGANTEA' is high-yielding on wet soils (Neenan 1980).

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[1]Lindroth 1979.

[2]Salo et al. 1977.

[3]Fege 1981.

[4]Lindroth 1979 and Stott,

[5]Siren 1980.

Trials in Europe have indicated willows to grow well on fine and medium textured soils.

Research in growing energy forests in Sweden has determined the minimum length of the growing season (based on the number of degree days above 5°C) as 900 degree-days (Perttu 1979). Other research in that country suggests that some high-yielding Salix viminalis clones require a heat sum of 1500°C while other willows show high yields with ⩾ 1300°C per growing season. Siren (1980) claims that S. caprea hybrids are suitable for coppice forestry in areas exceeding 900°-days.

An inventory of land for energy forests in Sweden is being compiled and includes areas that have a minimum soil depth of 70 cm (Lindroth 1979). No known soil depth requirements for willows are available. Also, the scale of the area studied in this project is such that no detailed information on soil depth is available and thus could not be used as a criterion.

3.2 Technical Considerations

Local topography is an important factor in determining the feasibility of establishing an energy farm. Since mechanization is of paramount importance in the management scheme (including planting and harvesting operations), it is necessary to eliminate those areas that have steep slopes. Fege (1981) suggests that mechanization can be employed on slopes up to 15%, Lindroth (1979) proposes the exclusion of land with slopes greater than 20%, and Salo et al. (1977) indicate that mechanical harvesting systems can be developed for energy farms on slopes up to 30% (17°). In this study, the more conservative estimate (slopes up to 15%) was employed to determine suitable areas.

Rockiness and stoniness are also important considerations. Areas with frequent exposure of bedrock are not conducive to mechanized operations. Also, substantial surface stoniness will involve increased site preparation costs.

The Newfoundland Soil Survey (1981) rates soil subclasses from I to IV based on the percentage of exposed bedrock. The use of machinery in areas that have over 25% exposed bedrock (⩾ III) is considered impractical. Based on this rating system, areas in this study, having in excess of 25% exposed bedrock are deemed unsuitable. The Newfoundland Soil Survey also rates soil subclasses in terms of surface stoniness from 0 (non-stony) to 5 (excessively stony; too stony to permit any cultivation). Accordingly, areas that are designated as excessively stony were eliminated.

3.3 Socio-economic Considerations

The amount of land suitable for energy plantations, in terms of the biological and technical considerations outlined above, will be reduced by factors such as conflicting land uses, accessibility, extent of area available, and hauling distance from site to market.

Lands committed to parks, wildlife sanctuaries, and urban and industrial areas are unavailable for energy plantations. Also, owners of commercial farms and productive timberland may not be interested in managing their land for energy plantations, but integration may be an attractive proposition of useful but substandard agricultural land.

Information on the minimum area necessary for an economically viable plantation is mostly speculative at present. The minimum land area would also vary from region to region depending on such factors as biomass productivity, market demand, and management practices (see Section 6).

Basic economic data on hauling distances from the energy farm to the point of utilization is readily available from reports on wood-chipping trials in Newfoundland. These trials, performed by Abitibi-Price and Bowater, have involved chip transportation from roadside to the mill. According to their experience, industry officials believe that at present oil prices, 50-65 km is the maximum hauling distance for energy chips. In the long term, as oil prices increase relative to wood costs, these distances can be extended.

4. CASE STUDY: COCHRANE POND - BAY BULLS BIG POND AREA

A landscape analysis method using maps, interpreted orthophotomaps, and aerial photographs was employed to determine suitable land for energy plantations.

The method initially to be used is that employed in Sweden whereby areas fulfilling selected criteria are plotted on maps. Areas which fulfill all the criteria are then designated as land for energy forests. This approach did not appear entirely satisfactory for this study for the following reasons. Firstly, the data they use deals only with soil and topographic characteristics. Secondly, the Swedish method demarcates areas with environmental restrictions, biological and technical restrictions, and areas with good potential for energy farms. While this approach serves as a good basis, in this study there was an apparent need to define potential areas more specifically; for example, because of the scale of the area studied and the other variables (socio-economic), there was wide variation between sites. This will be described in more detail below.

Initially three maps were constructed - soils and topography, vegetation cover, and land use. By super-imposing these map overlays on one another a final map was designed which, by means of a classification scheme, indicates variability of potential energy farm sites.

Since the scope of this project involved determining the availability and suitability of land for energy farms using willows and not actual clone/site matching, a map scale of 1:50,000 was considered adequate for the present purpose.

The area chosen for study lies between latitudes $47^{o}22'$ and $47^{o}30'$, and longitudes $52^{o}45'$ and $52^{o}58'$, south of the city of St. John's encompassing the town of Goulds in the east and west to Gull Pond (see Map 1).

Table 4.1 indicates the area to be generally climatically suitable for the establishment of osier-type energy farms based on a 2-3 year rotation. The length of the growing season at St. John's is greater than 1200 degree days. The closest meteorological station - St. John's West CDA - indicates an annual precipitation in excess of the above mentioned 64 cm requirement and is fairly evenly distributed throughout the year. The entire area is less than the maximum stated elevation of 400 m, the highest point being about 225 m.

Table 4.1 Mean daily temperature, degree days above $5^{o}C$, mean rainfall, and total precipitation for St. John's West CDA (1951-1980).

Month	Mean daily temperature	Degree days above $5^{o}C$	Mean rainfall	Mean precipitation
Jan	-3.8	0.8	91.7	180.8
Feb	-4.3	0.8	83.1	166.2
Mar	-2.0	1.8	82.9	150.5
Apr	1.6	6.7	87.0	126.2
May	5.8	58.0	95.3	106.8
Jun	11.1	186.1	78.7	79.8
Jul	15.6	329.6	73.8	73.8
Aug	15.5	325.8	114.7	114.7
Sep	11.6	199.1	106.4	106.4
Oct	7.1	82.4	142.4	145.3
Nov	3.5	28.2	148.9	167.8
Dec	-1.4	4.5	109.0	176.4

Source: Canadian Climate Normals, Vols. 2, 3, 4, Environment Canada, AES, 1982.

4.1 Soils and Topography

A map of soils and topographic restrictions was constructed at a scale of 1:50,000 (see Map 2). The information used for preparing the map was derived from the Newfoundland Soil Survey map at 1:100,000. The Soil Survey map is divided into soil series and further divided into subclasses on the basis of soil and topographic characteristics:

For example,

Soil Series			Subclass	Cr
Topography	Stoniness	Rockiness	example:	D41

whereby the elements of the denominator indicate the percent of slope, amount of stoniness, and percent of exposed bedrock. Soil texture and general drainage conditions are listed for the entire soil series and not individual subclasses. Soil depth is listed and generalized for only a few soil series. The lack of detailed information on soil depth precluded the use of this variable in determining suitable land.

In view of the number of criteria involved it appeared desirable to plot areas according to their degree of limitation rather than indicating areas simply as suitable or unsuitable. In this regard, each soil subclass was evaluated individually (see Table 4.2).

Areas designated as having severe limitations are those exceeding one or more limits as discussed in the previous section.

Suitable areas were further divided into sites with slight or no limitations and those with moderate limitations. The following explains this procedure:

- slope and drainage criteria remained constant for all areas
- areas with $\leq$ 10% exposed bedrock (rockiness Class I) and are non-stony to moderately stony (stoniness Class 0-2) were designated as having slight or no limitations
- areas with up to 25% exposed bedrock (rockiness Class II) and/or are very to exceedingly stony (stoniness Class 3-4) were designated as having moderate limitations.

Organic soils were delineated separately on the map. While peatlands represent underutilized and available land for energy farms, their commercial exploitation depends on numerous economic factors including drainage, specialized equipment and substantial fertilizer costs.

Table 4.2. Examples of soil and topography types and suitability.

Subclass symbol	Soil type	Parent materials	Slope (%)	Drainage	Bedrock	Surface stoniness	Surface texture	Land use and location on map 1	Suitability
Cr / 62	Orthic Humo-ferric Podzol	Medium textured, dark olive grey glacial till, derived mainly from grey slate and siltstone	Gently sloping 2-5% C	Moderately well-drained	-	Moderately stony: some interference with cultivation 2	Loam	Acid, low in natural fertility. Agricultural capability Class 4. Occurs NW of Fourth Pond. Cleared farmland.	S
Cr / D4I	Orthic Humo-ferric Podzol	"	Moderately sloping 5-9% D	"	2-10% exposed bedrock I	Exceedingly stony: considerable clearing required before cultivation 4	Loam	Acid, low in natural fertility. Agricultural capability Class 7. Occurs N of Cochrane Pond. Primarily low productive woodland with small parcels of cleared farmland	M(1)
Pat:Rc / F4III	Primarily Placic Ferro-Humic Podzol	Moderately coarse textured, dark brown glacial till, derived from sandstone, siltstone and acid volcanic rocks.	Steeply sloping 15-30% F	Poor to well-drained	25-50% exposed bedrock III	" 4	Sandy loam	Agricultural capability Class 7. Occurs E of Bay Bulls Big Pond. Low productive woodland.	V(1,2,3)
06 / B	Sphago and Mesic Fibric	Fibrous and partly decomposed moss peat, mainly Sphagnum moss	Very gently sloping 0.5-2% B	Very poorly drained	-	-	-	-	O

Limitations and Degree of Limitations

1. Surface stoniness
2. Exposed bedrock
3. Slope
4. Rapid drainage

S Slight or no limitations
M Moderate limitations
V Severe limitations
O Organic soils

Some areas on Map 2 denoted as having slight or no limitations and moderate limitations also comprise some organic soils. Likewise a few areas designated as organic soils also contain mineral soils. This is because the subclasses of the Soil Survey map often have a complex soil series (see example 3, Table 4.2). The first named soil series of a subclass occupies 40-80% of the area, and it was this first soil series that was used as the basis for whether a subclass would be regarded as a mineral soil or organic soil.

Some preliminary figures of potential areas for energy farms according to the soil and topography criteria mentioned above are as follows:

	Approximate area (ha)	(% of total land area)
Areas with slight or no limitations	832	(4%)
Areas with moderate limitations including organic soils	17 700	(81%)
Areas with severe limitations	3 300	(15%)
Total land area	21 832	
Study area	23 541	

4.2 Vegetation Cover

In order to locate areas available for energy farms such as marginal and abandoned farmland, hardwood and softwood scrub forest, heathland (and possibly peatlands), sources indicating present vegetation cover were consulted. The data primarily used were from 1:12,500 orthophotomaps,[1] supplemented with 1:12,500 (approximately) aerial photographs[2] and the 1:50,000 Cochrane Pond Farmland Development Project Map.[3]

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[1]Provincial Department of Agriculture & Forestry, Land Use Map, 1978.

[2]Provincial Department of Forestry, 1978.

[3]Provincial Department of Rural, Agricultural & Northern Development, Soil and Land Management Division, 1982.

As the orthophotomaps had to be scaled down to 1:50,000, thus obscuring some detail, it was necessary to group the various vetetation types. The groupings are as follows:

Vegetation Cover (Map 3)	Orthophotomap
Cleared farmland	Cropland
	Hayland
	Pasture — improved
	Pasture — unimproved
	Improved bog (cultivated or just drained)
	Idle land
Low productive woodland	Unproductive woodland
	Unproductive woodland burn
	Productive woodland burn
	Productive woodland cutover
Heathland	Sand and rock barrens
Unimproved bogs	Unimproved bogs/swamps

These groupings were desirable for the following reasons. First, in terms of the costs involved in establishing an energy plantation, the cleared farmland category (including cropland, pasture, etc.) would require relatively less site preparation than compared to the low productive woodland category (including unproductive woodland, cutovers, etc.). Second, there were some interpretation problems with the orthophotomaps. For example, improved bogs were not distinguished as being under cultivation or simply drained. Also, there may have been some interpretation overlap between hayland and pastureland, and similarly between sand and rock barrens.

Idle farmland appears to be particularly suitable for energy farms at least from a socio-economic standpoint and could warrant a separate category. However, the small parcels of land and their patchy distribution in this study area necessitated the grouping of these areas under the cleared farmland category.

Most of the areas designated as cleared farmland in the Goulds region - east and southeast of Cochrane Pond to Bay Bulls Big Pond - are divided into small fields under crop and hay. Some of the better soils, rated as Class IV on the soil capability map, are in this region. The production levels of the cropland were not determined in this study; hence the economic attractiveness of switching to energy crops cannot be assessed at this point. The same applies to land devoted to hay. Hay production, however, is in great demand. The dairy industry of the St. John's region has approximately 40 farms (including 28 farms in the Goulds-Kilbride area). For this industry to be self-sufficient in feed for present production, a total land requirement of 2 400 - 3 200 hectares has been estimated. Presently the farms have 1 720 ha. The result is that farmers must import hay at $175 per ton. Local hay production, costing $50 per ton, is therefore very cost competitive and necessary for this industry (Dept. of Rural, Agricultural and Northern Development, 1982). Under these circumstances, the likelihood of owners of hayland converting to energy farming seems doubtful, however significant areas within hay producing sites not suitable for hay, i.e. low productive hay sites or marginal pasture soils, could be used for energy crops.

Inconsistencies occur in the location and extent of areas delineated as bogs on the vegetation cover map and areas denoted as organic soils on the soils and topographic map. This can be explained by the scale of the two map sources - the smaller scale of the Soil Survey map means generalization and also, as mentioned in the previous section, soil subclasses are not homogeneous in that they may contain both mineral and organic soils.

In the eventuality of utilizing peatlands for energy farms, the types and extent of these wetlands were determined for the study area (see Table 4.3). The predominant bog type in this area (slope bog) is the most commonly found in eastern and southern Newfoundland (Pollett and Wells 1979).

Table 4.3 Type and extent of peatlands in study area.

Deposit name	Area (ha)
Slope bog	3 018
Domed bog	195
Basin bog	3
Stream marsh	2
Stream swamp	14
Lentic marsh	7
Organic complexes:	
Slope bog - lentic marsh	4
Slope bog - stream marsh	91
Slope bog - slope fen	5
Slope fen - stream marsh	1
Slope bog - patterned fen	55
Domed bog - slope bog	607
Slope bog - domed bog	210
	4 212

Source: Peatland Inventory, Eastern Newfoundland, Volume tables (Bay Bulls maps 1N/7 31, 32, 41, 42), 1980.

4.3 Land Use

The energy plantation is a new land use and as such may compete with existing land uses. Hence, a map indicating areas of alienated lands and designated lands is necessary to completely assess the availability of land for energy crops.

One to fifty thousand (1:50,000) Land Use Atlas maps[1] were used and certain areas updated with the 1:50,000 CPFDP map[2] to construct Map 3. The first source is particularly helpful as it shows administrative, designated, and restricted areas including both present and proposed land uses.

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[1]Department of Forest Resources & Lands, Land Management Division, Land Use Atlas, 1982.

[2]Department of Rural, Agricultural & Northern Development, Soil and Land Management Division, Cochrane Pond Farmland Development Project, 1982.

On Map 4 areas unavailable to energy farms include provincial parks and a restricted area (seaplane airstrip). Map 3 includes build-up areas (urban and industrial) that must also be eliminated.

Designated areas within the study area include the Newfoundland Light & Power watershed and land within a 1.6 km radius of a waste disposal site. Neither of these areas should pose land use problems for energy farming. In the NL & P designated watershed areas, the Company has rights "to regulate the water levels on ponds and streams..." and the authority "to restrict traffic on roads which they have constructed to service their facilities".[1]

The Agricultural Development Area (ADA) comprises a sizeable portion of the study area. Present agricultural projects are confined to the Cochrane Pond - Bay Bulls Big Pond area. A short discussion on the purpose of the ADAs in the Province is appropriate in terms of how energy plantations may or may not be a viable alternative in some of the areas.

A number of regions across the Province have been designated by the government as ADAs. These areas have been selected based on soil surveys, market potential, current levels of production and growth potential. It is proposed that these areas be designated under The Development Areas (Lands) Act 1976 meaning "that land was not compatible with agriculture would be restricted or tightly controlled".[2] The aim of the regulations is "to preserve and protect land from conflicting uses that irreversibly remove it from agricultural production".[3] By these definitions, the establishment of energy farms in these areas can be regarded as an appropriate land use.

The Cochrane Pond Farmland Development Project, as part of the St. John's ADA, is a far more specific development plan. The project, issued by the Dept. of Rural, Agricultural and Northern Development (1982), emphasizes the land constraint problem facing farmers in the St. John's region. The project is designed to provide

> "An additional land base for the production of forage for the dairy industry, and for the establishment of animal confinement areas."[4]

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[1] Manual for the Land Use Atlas and Referral Guidelines, Land Management Division, n.d.

[2] Newfoundland Soil Survey and Land Use Program, 1981, p. 18.

[3] Ibid, p. 19.

[4] CPFDP, Department of Rural, Agricultural and Northern Development, Soil and Land Management Division, 1982, p. 1.

The components of the area comprise two pastures, a forage area, and a swine confinement area. In the Goulds forage area about 20% (431 ha) of the land is under agricultural lease application associated with the project. The 431 ha have been cleared and some areas already seeded. The Department is seeking further approval for the allocation of 495 ha for forage production and 18 ha for confinement lots. As previously mentioned, hay is imported from outside the Province. By bringing into production 430 ha of forage land in this area the Department projects a savings of 0.4 million dollars per year.[1]

The Department is also seeking approval for the allocation of 610 ha for animal confinement lots in the proposed Cochrane Pond Confinement Area (total area 1 189 ha).

In order to obtain the lease for the assigned lots in the forage area, the individual farmers are subject to terms and conditions, two of which state:

> "The land will be developed and maintained to provide forage and pasture for dairy operators in the Goulds - Kilbride - Mount Pearl Region."
>
> "Sale or transfer of leases must be to operators who will maintain forage production."[2]

Similarly, farmers selected for confinement area operations are subject to the condition that "Sale of transfer of leases must be to operators who will maintain confinement operation."[3] The Foxtrap pasture is a community pasture operated by private operators; the Cochrane Pond Pasture will also be similarly controlled. Obviously to accommodate energy farming as an agroforestry crop the terms and conditions would have to be extended to allow farmers to capitalize in this industry.

4.4 Accessibility

Within the study region the most accessible areas are those within the ADA. A road parallel to the Bay Bulls Highway from Bay Bulls Big Pond northward facilitates access to the eastern areas. A Goulds by-pass road is to be constructed diagonally between these two others. Land between Northern Pond and Big Northern Pond is accessible by pasture roads via the Trans-Canada Highway on the west.

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[1] CPFDP, Department of Rural, Agricultural and Northern Development, Soil and Land Management Division, 1982, p. 1.

[2] CPFDP, Appendix I, 1982.

[3] Ibid, Appendix II.

5. FUEL REQUIREMENTS OF POTENTIAL MARKETS

A fuel consumption study was initiated for selected institutional buildings across the Province. From this information estimates of fuelwood equivalents were calculated and also estimates made of the size of energy plantations required to meet fuel demands.

Schools in the eastern region of the Province (excluding the St. John's district) were selected for the study. The school boards contacted, by letter and some also by telephone, included five integrated school boards, five Roman Catholic school boards, the Pentecostal Assemblies School Board, and the Seventh Day Adventist School Board. Although contacted a second time a few months later, only one school board has returned the survey. This lack of response is mostly due to there being few personnel during the summer months and it was generally felt by a few officials that the winter months would be a more suitable time to conduct the study.

The Provincial Department of Public Works and Services was contacted for information on government run hospitals and district vocational schools across the Province. Map 6 indicates the location of the buildings surveyed.

This particular fuel consumer group is considered as a potential market for a number of reasons. For example, hospitals, operating on a 24-hour basis, require a long term and continuing supply of fuel. Electrical heating facilities are not recommended because of the possibility of cuts.[1] However, locally established energy farms providing a continuous supply of wood chips may be regarded as a desirable alternative fuel source. Many of the buildings surveyed are rurally located where land use conflicts are likely to be less. Also, the Department of Public Works and Services has been conducting energy audits on public buildings across the Province (e.g. vocational schools, hospitals, arts and culture centres, court houses, etc.) since 1979.[2] Engineering consultants studying these various buildings have made architectural, operational, and mechanical (e.g. heating and lighting systems) energy saving recommendations. The majority of these changes represent short-term payback benefits. In terms of long-term benefits and government interest in energy saving changes, these buildings may be prime candidates for the conversion to, or supplementing of, fuelwood for heating purposes.

5.1 Fuelwood Equivalency

The data for the annual fuel oil consumption of the various buildings was given in volume (gallons) or energy units (mJ/m^2) and cost (see Table 5.1). Fuel equivalency between various fossil fuels and wood

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[1] Pers. comm. Bill Trask, Nfld. Light & Power Co.

[2] Pers. comm. Eugene Upshall, Prov. Department of Public Works and Services.

Table 5.1. Fuel data of selected institutional building.

Building	Remarks: General occupancy pattern	Heating medium	Fuel source	Annual fuel consumption (gallons)	Fuel cost per year	o.d.t. fuel equivalence	Land area requirement (ha/yr)
Old Perlican Cottage Hospital		Steam	Furnace oil	13,545		176	16-22
Markland Cottage Hospital			Furnace oil	7,858		102	9-13
Bonne Bay Cottage Hospital		Hot water	Furnace oil	10,074		131	12-16
Placentia Cottage Hospital		Steam	Furnace oil	14,243		185	17-23
Bell Island Hospital		Hot water	Furnace oil	43,953		571	52-71
Botwood Cottage Hospital		Steam	Furnace oil	29,186		379	34-47
Come-by-Chance Cottage Hospital		Hot water	Furnace oil	6,081		79	7-9
Grand Bank Cottage Hospital		Steam	Furnace oil	20,347		264	24-33

... (Con'd.)

Table 5.1 (cont'd.)

Building	Remarks: General occupancy pattern	Heating medium	Fuel source	Annual fuel consumption (gallons)	Fuel cost per year	o.d.t. fuel equivalence	Land area requirement (ha/yr)
Burin Cottage Hospital	-	Hot water	Furnace oil	12,320		160	15-20
St.Lawrence Cottage Hospital	-	Steam	"	24,895		323	29-40
Bonavista Cottage Hospital	-	Steam	"	6,760		88	8-11
Springdale D.V.S.	Approx. 238/day (excl. evn. classes)	Hot water	#2 oil	1,224 mJ/m^2 (1978-80 avg)	$30,900	401	36-50
Carbonear D.V.S.	9½ mths/yr 5 days/wk.	Hot water	#2 oil	78,315 (1978-79 avg)		1,017	93-127
Bell Island D.V.S.	372 max/day 9½ mths/yr 5 days/wk Serviced yr round	Hot water	#2 oil	35,180 (1978-80 avg)		457	42-57
Gander D.V.S.	Approx. 433/day (incl. evn. classes) 8½ mths/yr, 5 da/wk Serviced yr round	Hot water	#2 oil	72,776 (1978-80 avg)		945	86-118
Baie Verte	Approx 160/day 9½ mths/yr, 5 da/wk. Serviced yr round	Hot water	#2 oil	1155 mJ/m^2 (1978-80 avg)	$30,900	401	36-50

... (Cont'd.)

Table 5.1 (Concl'd.)

Building	Remarks: General occupancy pattern	Heating medium	Fuel source	Annual fuel consumption (gallons)	Fuel cost per year	o.d.t. fuel equivalence	Land area requirement (ha/yr)
Seal Cove D.V.S.	Approx. 390/day 9½ mths/yr, 5 da/wk Serviced yr round	Hot water	#2 oil	74,255 (1978-80 avg)		964	88-121
Happy Valley D.V.S.	8½ mths/yr 7 days/wk	Hot water		1,642 mJ/m^2 (1978-79 avg.)	$90,450	1,175	107-147
Port de Grave Pentecostal Elementary	-		Fuel oil	2,111	$2,200	27	2-3
Victoria Bethel Pentecostal Academy	-		Fuel oil	3,430	3,600	45	4-6
College of Fisheries	550/day, 5 da/wk 9½ mths/yr		Fuel oil	1,590 mJ/m^2 (1978)	$57,537	747	68-93

(accounting for differences in combustion efficiencies) can be estimated, according to Arola (1976) as one ton of green wood approximately equivalent to one barrel of oil, or two barrels of oil if oven dry. This agrees with Silverside's (1981) estimate of one green tonne approximately equivalent to 1.10 barrel of residual oil. Based on these estimates, the amount of fuelwood required by each building was calculated as

1 o.d.t. = 77 imp. gal. (2.2 barrels of oil)

In some instances, the annual fuel consumption was given in energy units (mJ) rather than volume (gal.). For these buildings the annual fuel oil cost was used to determine o.d.t. fuel equivalence. As one gallon costs \$1,[1] the amount of the annual fuel oil cost was regarded as being the equivalent amount in gallons.

The land area required to meet the fuelwood demand is based on estimated Salix biomass yields. A yield of 8-11 o.d.t./ha/yr is considered feasible in Newfoundland. Based on European experience (see Table 5.2), particularly in boreal regions of Scandinavia and clonal trials at Pasadena and St. John's, Newfoundland, this is a reasonable estimate.

At this stage some very preliminary results of energy plantation land requirements can be given:

	Land area requirements (8-11 o.d.t./ha/yr)
Cottage hospitals (10)	17-23
Other hospitals (1)	52-71
District vocational schools (7)	70-96
Other Schools (2)	3-5

5.2 Discussion

The fuelwood equivalence and land area requirements for the different buildings are, by necessity, approximations. However, a recent detailed study of the present and proposed heating facilities of the Gander Hospital indicate the fuelwood requirement calculations to be fairly realistic as follows:

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[1] Government buildings only, Provincial Energy Audits, Vol. II, Provincial Department of Public Works and Services.

Table 5.2. Biomass yields of *Salix* spp.

Species	Location	Above ground yield (o.d.t./ha/yr)
S. cv. 'Aquatica'[1]	Finland, Arctic Circle	9
S. alba[2]	Sweden	8.9-26.1
S. fragilis[2]	Sweden	11.5-21.3
S. x Aquatica Gigantea[3]	U.K.	9.7-18.6
S. viminalis (and hybrids)[3]	U.K.	13.5-23.5
S. triandra[3]	U.K.	10.5
S. purpurea[3]	U.K.	9.7
S. alba[3]	U.K.	11.6

Sources: 1. Veli M. Pohjonen, 1980.
2. Siren and Sivertsson, 1976.
3. Stott *et al.*, 1980.

Gander Hospital, annual fuel consumption - 170,000 gal. bunker 'C'

o.d.t. required as per Duffett, P., n.d.	o.d.t. required as per this study	Over-estimate
≃ 2089 (4596 green tons given in reference)	≃ 2208	6%

The economic feasibility of institutional buildings converting to wood-burning or supplementing their heating requirements with wood necessitates detailed research outside the scope of this project. These studies will have to consider parameters such as proximity of the building to suitable sites for energy farms, and the availability and amount of storage space required for wood chips.

6. ECONOMIC ANALYSIS OF SALIX ENERGY PLANTATIONS

This part of the study entailed a preliminary evaluation of the economic feasibility of a willow energy plantation. A number of economic studies have been undertaken to project costs of energy chips and wood fibre produced in short-rotation systems (Rose and DeBell 1978, Howlett et al. 1977, Rowersox and Ward 1976, Raitanen 1980). The results are quite variable due to differences in the design of the plantations and the methodologies employed to assess the production costs.

The approach taken in this study is divided into four parts as follows:

- conceptualization of plantation design
- data collection of production costs and revenues
- sensitivity analysis of data
- identification of high production costs and suggestions for their reduction

6.1 Energy Plantation Design

The design of the plantation was patterned on the basis of discussions with Mr. Robertson and recent literature on short-rotation energy farms. The characteristics of the design are summarized in Table 6.1 and are discussed briefly below.

Based on growth trials in Newfoundland, the productivity of Salix biomass is estimated at a minimum of 15 green tonnes/ha/year Actual yields obtainable will depend on planting densities, rotation period and various site factors. Three years was the rotation length accommodated for in this study. The productive lifetime of a willow stool was not taken into account. Stools in Europe have lasted many decades; hence, it is reasonable to assume that the productive lifetime of a single stool will last for generations if properly managed (Robertson pers. comm.). The treatments, and hence costs, of site preparation will

Table 6.1. *Salix* energy plantation design.

Characteristics	Remarks
Plantation size	Thirty hectares.
Productivity	Fifteen green tonnes/ha/yr.
Rotation period	Coppicing every three years.
Establishment:	
Site preparation	Rootraking and rockpicking; contractor mechanized operation.
Planting	Density of 32 000 cuttings/ha. Costs include purchase of willow cuttings and mechanical planter, contractor operation.
Maintenance:	
Fertilization	Initial application of 15-15-15 NPK, 300 kg/ha plus ammonium nitrate, 200 kg/ha. Annual application of same. Lime treatment, 4000 kg/ha, every seven years.
Protection	Insecticides applied annually. Costs include materials and aerial application.
Overheads	Licence fees, non-wage benefits for two part time employees, miscellaneous expenses.
Harvesting and transportation:	
Harvesting and chipping	In autumn/winter. Brushcutting machine and small chipper.
Transportation	Contractor pallet truck with 9.6 t capacity. Hauling distance 50 km.

necessarily vary according to site conditions; for example, wetlands require drainage treatments, old-fields may need treatments to eradicate competitive vegetation and forest sites may require prescribed burning, clearcutting, or scarification. For this analysis a mechanized operation involving two preparatory treatments were taken into account, namely root-raking and rock-picking. These were considered important due to the inherent stoniness of many Newfoundland soil types.

Salix reproduce vegetatively by cuttings successfully. Experiments conducted in Bowring Park, St. John's and Pasadena have shown that midsummer willow leaf cuttings root within three to four days. Direct seeding under conditions other than those found in a tree nursery incurs numerous risks and uncertainties (Howlett et al. 1977). Hence, establishing willow stands from cuttings is the most advantageous method from a management standpoint. The management system envisioned includes high density plantings (estimated 32 000 cuttings/ha for osiers). Hand planting at these densities is not economically viable.[1] Mechanized planting of hardwood cuttings has been investigated with successful results and at reasonable costs (Pohjonen 1980, Neenan 1980). Tree planting machines have been modified to take into account the narrow row spacings that are an intrinsic characteristic of short-rotation systems (Fege 1981). It is not yet known what machine would be suitable to Newfoundland conditions for planting willow cuttings, however, it may be similar to the machine used for stony ground in Sweden. The cost of mechanized planting in this analysis was determined from U.S. and Irish sources.

Cultural practises involved fertilization and protection. An annual application of a standard NPK fertilizer and another treatment of ammonium nitrate was viewed as necessary to maintain yields and basic soil fertility. The frequency of harvests and large amounts of biomass removed greatly affect soil fertility. Pohjonen (1980) claims nitrogen fertilizer to be the largest single energy input in willow plantations. Fege (1981) suggests that harvesting after leaf fall will improve the nutrient status of the stand since foliage contains a large portion of the nutrients. The acidic nature of the majority of soil types in Newfoundland necessitates the application of lime for some species. In this study, an application of lime once every seven years was considered.

The model assumes an annual application of insecticides may be necessary. Both the cost of material and application are included in the analysis. Information for this treatment was used from the willow growth trials in Pasadena, Newfoundland. The potential cost effectiveness of pest control is not presently known (Inman 1977). Certain studies

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[1] Raitanen (1980) asserts that the cost of hand planting at densities of 35 000 cuttings/ha is $1200 Canadian.

have shown (Fege 1981) that weed control is sometimes necessary during the first year or two of stand establishment, as competition for light, moisture, and nutrients can reduce coppice growth. This is likely to be the case for tree establishment rather than for osiers.

Other annual maintenance costs included here are overheads for two part-time employees.

The harvesting systems of short-rotation energy plantations (2-3 year old osiers) are considered to more closely resemble agriculture (i.e. forager-type harvesting equipment) than forestry. Researchers in Europe and North America have started cooperating on harvester design specifications (Fege 1981). It is generally concurred that these new systems will reduce harvesting costs and minimize field traffic that could otherwise impede biomass productivity (Fege 1981, Rose and DeBell 1978, Inman 1977). For this analysis a type of brushcutting machine and a small chipper was considered. The costs used were based on Newfoundland and Irish experience.

The transportation costs for chips hauled from plantation to site of utilization were based on recent chipping trials performed by Abitibi-Price and Bowater. A hauling distance of 50 km was used - this is based on Newfoundland industry experience and officials regard 50-65 km as a maximum hauling distance for energy chips.

6.2 Analysis and Results

The present worth of individual production costs and revenues was calculated at three discount rates for sensitivity analysis over a period of 12 years (four rotations). A basic assumption of the analysis is that the relative price difference between oil and wood is constant. The breakdown of production costs by operation (Table 6.2A) enables a determination of their individual contribution to the total production cost.

The revenues are based on a fuel equivalence value for harvested energy chips (calculated at 1.1 barrel of oil per green tonne equivalent. Revenues were calculated using four approaches; three based on oil replacement values (domestic crude, consumer, and world price), and one current price level for energy chips (Table 6.2B). From a national perspective the value of wood chips relative to world oil price, appears to be a realistic method of assigning full economic values to energy wood.

At a discount rate of 5%, maintenance costs comprise the largest portion of total production costs (42.0%) followed by harvesting and transportation (34.1%) and establishment costs (23.9%). This trend is the same at all three discount rates. Maintenance and harvesting and transportation costs can be expected to increase in the future if productivity remains constant and the cost of commercial fertilizers and fuel, for example, accelerate.

Table 6.2. Economic analysis of production costs and revenues for a willow energy plantation in Newfoundland.

6.2A Present value of costs in 1983.

Operation	$ Cost factors per ha	$ Cost factors 30 ha	$ at discount rates of (% of total production costs) 3%	5%	7%
Site preparation	300	9000	9000 (6.6)	9000 (7.2)	9000 (7.8)
Willow cuttings	256	7680	7680 (5.6)	7680 (6.2)	7680 (6.7)
Planting	100	3000	3000 (2.2)	3000 (2.4)	3000 (2.6)
Initial fertilization	335	10050	10050 (7.4)	10050 (8.1)	10050 (8.7)
Overheads	45	1350	13438 (9.9)	11965 (9.6)	10723 (9.3)
Protection	31	930	9257 (6.8)	7725 (6.2)	6974 (6.0)
Periodic fertilization	335	10050	26076 (19.1)	23792 (19.0)	21793 (18.9)
Lime treatment	400	12000	10050 (7.4)	8955 (7.2)	7996 (6.9)
Harvesting/ transportation	480	14400	47765 (35.0)	42509 (34.1)	38067 (33.0)
Total present value of costs:			136316	124676	115283

6.2B Present value of revenues in 1983

Approach	Description	$ Revenue/ha
1	Current price for energy chips	315
2	Domestic oil cost replacement value	365
3	Consumer oil cost replacement value	525
4	World oil cost replacement value	624

Revenue option	$ Revenue 30 ha	$ at discount rates of 3%	5%	7%
1	9 450	31 347	27 896	24 981
2	10 950	36 321	32 325	28 947
3	15 750	52 243	46 495	41 636
4	18 720	62 095	55 263	49 467

In terms of individual production costs, harvesting and transportation contribute (at the 5% rate) the most significant portion (35.0%) followed by annual fertilizer treatments (19.1%) and overheads (9.9%).

A comparison of the total production costs with the revenue for approach four indicates that over the 12 year period, only 43-46% (7-3% discount rates) of the total production costs are recovered. Or viewed another way, the cost of producing one green tonne of energy chips is $256 to $303 while expected revenues for that amount of biomass ranges from $110 to $138.

6.3 Discussion

Given these preliminary estimates of current costs and revenues the economic viability of a willow energy plantation in Newfoundland appears poor.

An important determinant influencing production costs of an energy plantation is productivity. That is, the more productive a stand the less amount of land required to attain a given amount of biomass. The costs that are sensitive to changes in productivity include site preparation, planting, protection, and liming (Inman 1977). The application costs of fertilizer are also influenced by yield but the costs of materials are not - that is, a higher level of stand productivity will likely demand a greater input of fertilizer. As mentioned earlier in this section, the 15 green t/ha/yr productivity level is estimated as a minimum; productivity may reach up to 22 green t/ha/yr (Robertson 1981).

Another factor possibly influencing production costs is the size of the plantation. It has been suggested that larger commercial operations will be more economical (Intergroup 1982).

As fertilizer costs play a key role in determining total production costs it is appropriate to consider here alternative measures. Previously mentioned is the notion that harvesting following abscission maximizes the nutrient efficiency of the crop. However, this still means that the soil experiences a nutrient drain. A few options are available to increase soil fertility. For example, young trees have a greater nutrient concentration than mature trees. This is because a significant proportion of the former's biomass is bark which has a high nutrient content (Raitanen 1930, Pohjonen 1980). Therefore, returning the wood ash to the plantation site will return some nutrients to the soil.

Costly commercial fertilizers could be supplemented by the application of municipal sludge or industrial effluents containing nitrogen and organic matter. Experiments of this kind have had positive results in Ontario (Raitanen 1980).

Soil fertility can also be enhanced by utilizing leguminous crops to fix nitrogen. Mix plantings of Populus and legumes increased the first year height growth of the former in four out of six trials (Zavitovski et al. 1979, cited in Pege 1981). The planting of leguminous crops between rows may also deter weed growth.

In conclusion, modification of production costs appears possible. However, the lack of accurate cost data for Newfoundland conditions makes a more realistic analysis particularly difficult. A trial is viewed as imperative to obtain these values. Also, continued field trials are essential to determine optimum planting densities, rotation periods, and other factors contributing to biomass productivity.

7. SURVEY OF NATIVE WILLOWS

Part of the project involved a survey of native willows in order to:

- obtain specimens for herbarium use and taxonomic studies
- locate willows for later collections for propagation purposes

A systematic survey was conducted across the Province during the first two weeks of August. Labrador and the Northern Peninsula were excluded due to the time factor involved. Specimens of tree and shrub willows were collected at regular intervals (≈ 20 miles) along the main highways and also around lakesides, rivers, and shorelines. The NeFRC herbarium specimens of willows previously collected have a clustered distribution; most of them were collected in the Humber district and the Northern Peninsula. The specimens collected in 1982 provide a more complete collection. May 7 shows the location of samples collected the summer of 1982.

The exact location of each specimen was noted. It is intended that cuttings, to be obtained from some of these sites in 1983, will be grown and their rates of growth compared with exotic willow species presently being studied in Newfoundland. A few cuttings of different species were taken and are being cultivated at Bowring Park, St. John's. However, it is preferable that cuttings be obtained in the spring or autumn to ensure higher survival rates.

Habitat descriptions of each specimen were done and taxonomic identification made at the NeFRC where the specimens have been deposited.

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BIBLIOGRAPHY

Arola, Rodger A. 1976. Wood fuels - How do they stack up? Presented at Energy and the Wood Products Industry Meeting, Atlanta, Georgia, November.

Bowater Newfoundland Limited. 1982. Harvesting forest biomass as an alternate fuel. ENFOR Project P-191.

Bowersox, T.W. and W.W. Ward. 1976. Economic analysis of a short-rotation fiber production system for hybrid poplar. J. For. 74:750-753.

Duffett, Paul (n.d.) Commercial wood heating in central Newfoundland. Dept. of Forestry & Agriculture (mimeo).

Energy, Mines & Resources, Canada. 1982. Canada Oil Substitution Program.

Environment Canada. 1982. Canadian climate normals. Vol. 2, 3, 4, AES.

Fege, Anne S. 1981. Silvicultural principles and practices in short rotation energy forestry in temperate zones. Monograph for International Energy Agency, Forestry Energy Agreement, Planning Group B.

Forest Resources & Lands, Newfoundland (n.d.). Manual for the Land Use Atlas and Referral Guidelines. Land Management Division.

Heringa, P.K. 1981. Soils of the Avalon Peninsula, Newfoundland, Report No. 3: Newfoundland Soil Survey. Agriculture Canada, Land Resource Research Institute Publication 113.

Howlett, K. et al. 1977. Silvicultural biomass farms, Vol. II: The biomass potential of short rotation farms. MITRE Corp. Tech. Rep. No. 7347. National Tech. Info. Serv., U.S. Dept. of Commerce, Springfield, Va.

Inman, R.E. 1977. Silvicultural biomass farms, Vol. I: Summary. MITRE Corp. Tech. Rep. No. 7347. National Tech. Info. Serv., U.S. Dept. of Commerce, Springfield, Va.

Intergroup Consulting Economists Ltd. 1982. Availability and cost of forest biomass in Canada. ENFOR Project P-224(1).

Lindroth, S. 1979. Land inventory for energy forests - methods and preliminary results. Symposium proceedings, International Energy Agency (IEA) Planning Group on Growth and Production, Bogesund, Stockholm, Sept. 1979. Tech. Rep. No. 8, K. Perttu (ed.).

Neenan, M. 1980. Ecological basis for selection of species. *In* Production of energy from short rotation forestry, Neenan & Lyons (eds.), An Foras Taluntais: Dublin.

Newfoundland Soil Survey & Land Use Program. 1981. Published jointly by Canada/Newfoundland Agriculture Development Subsidiary Agreement.

Northland Associates Ltd. (n.d.). Fuelwood consumption in Newfoundland. Nfld. For. Res. Ctr., Info. Rep. N-X-177.

Peatland Inventory, Eastern Newfoundland, Volume Tables. 1980.

Perttu, K. 1979. Abiotic premises for growing energy forests. *In* Symposium proceedings, International Energy Agency (IEA) Planning Group on Growth and Production, Bogesund, Stockholm, Sept. 1979. Tech. Rep. No. 8, K. Perttu (ed.).

Pohjonen, Veli M. 1980. Solar energy through energy farming - goals, means and plans in Finnish energy forestry. ECE seminar on technologies related to new energy sources; Jülich, Fed. Rep. of Germany, Dec. 1980.

Pollett, F.C. and E.D. Wells. 1979. Peatlands of Newfoundland, an overview. *In* The Diversity of Peat. Pollett, Rayment, and Robertson (eds.). Nfld. & Labrador Peat Assoc., St. John's.

Public Works and Services, Newfoundland. 1981. Provincial Energy Audits, Vol. II.

Raitanen, William E. 1980. Farming fast growing hardwoods for energy in Ontario, Canada. 2nd Western Hemisphere Energy Symposium, Rio de Janeiro, Brazil, Sept. 1980.

Robertson, A.W. (in prep.). Willows of Europe: An introduction and their potential for SRF energy plantations.

Robertson, A.W. 1981. Salix for biomass fuel and energy conservation in Newfoundland. Proceedings 4th Bioenergy R & D Seminar, Winnipeg, Man. March 1982.

Rose, A.W. and D.S. DeBell. 1978. Economic assessment of intensive culture of short-rotation hardwood crops. J. For. 76:706-711.

Royal Commission on Forest Protection and Management Report. 1981. Part II.

Rural, Agricultural and Northern Development, Newfoundland. 1982. Cochrane Pond Farmland Development Project. Soil and Land Management Division.

Salo, D.J. et al. 1977. Silvicultural Biomass Farms, Vol. III: Land suitability and availability. MITRE Corp. Tech. Rep. No. 7347. National Tech. Info. Serv., U.S. Dept. of Commerce, Springfield, Va.

Silversides, C.R. 1981. Forest biomass for energy and forest industries. Reprint from Pulp and Paper Canada.

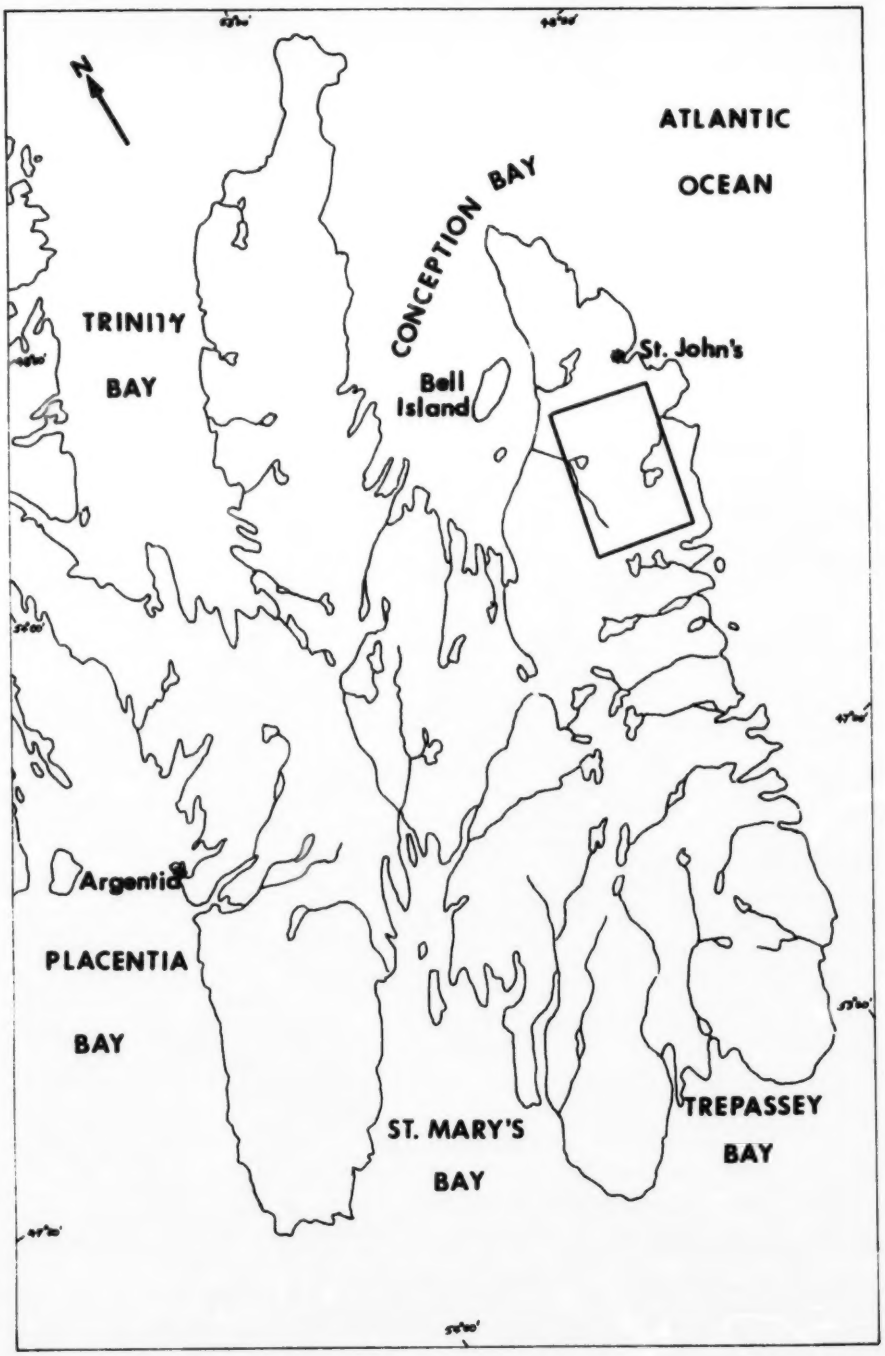
Siren, Gustaf. 1980. Energy forestry research in Sweden. Proceedings Bio-Energy 1980 World Congress and Exposition, Atlanta, Georgia.

Stott, K.G. et al. 1980. Coppice willows for biomass in the U.K. Paper to the International Conference on Energy from Biomass, Brighton, England. Long Ashton Research Station, U. of Bristol, England.

Wilton, W.C. and W.P. Duffett. 1980. Whole tree chipping for hogged fuel in Newfoundland. ENFOR Project P-115, Nfld. For. Res. Ctr. Info. Rep. N-X-186.

Map 1: Location of Cochrane Pond - Bay Bulls

Big Pond Case Study Area



SOIL & TOPOGRAPHIC RESTRICTIONS

- Slight or no limitations
- Moderate limitations
- Severe limitations
- Organic soils

Source: Soils of the Avalon Peninsula, Newfoundland Soil Survey, Report No. 3, 1981

Scale 1:50,000

1000 0 1000 2000 3000
Metres

CONTOUR INTERVAL 50 FEET

Base map from SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES Map IN/7

Cartography by Memorial University of Newfoundland Cartographic Laboratory © 1982

VEGETATION COVER

- Cleared farmland
- Low productive woodland
- Heathland
- Unimproved bogs
- Urban & industrial areas

Source: Forestry & Agriculture Ortho photo maps, 1978
Interpreted aerial photos, Forestry & Agriculture, 1978
Cochrane Pond Farmland Development Project Map, Soil Land Management, Department of Rural Agricultural and Northern Development, 1982

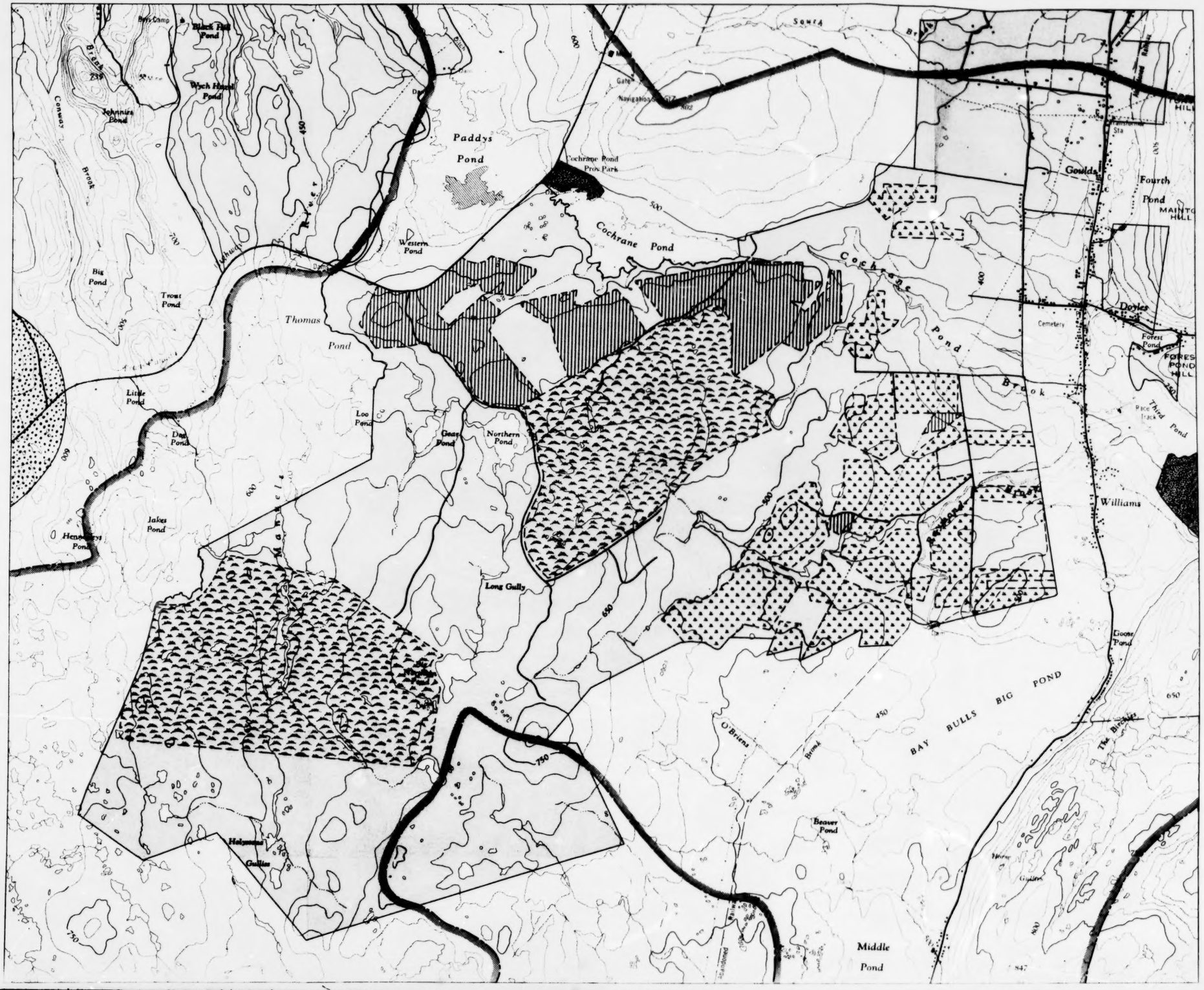
Scale 1:50,000

1000 0 1000 2000 3000
Metres

CONTOUR INTERVAL 50 FEET

Base map from SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES Map IN/7

Cartography by Memorial University of Newfoundland Cartographic Laboratory © 1982



LAND USE

- Agricultural Development Area
- Pasture
- Proposed Forage Area
- Proposed Confinement Area
- Provincial Park
- Restricted Area
- Designated Newfoundland Light and Power watershed
- Designated waste disposal site

Source: Land Use Atlas, Land Management Division, 1982
Cochrane Pond Farmland Development Project, Soil and Land Management, Dept. of Rural, Agricultural and Northern Development, 1982

Scale 1:50,000

1000 0 1000 2000 3000
Metres

CONTOUR INTERVAL 50 FEET

Base map from SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES
Map IN/7

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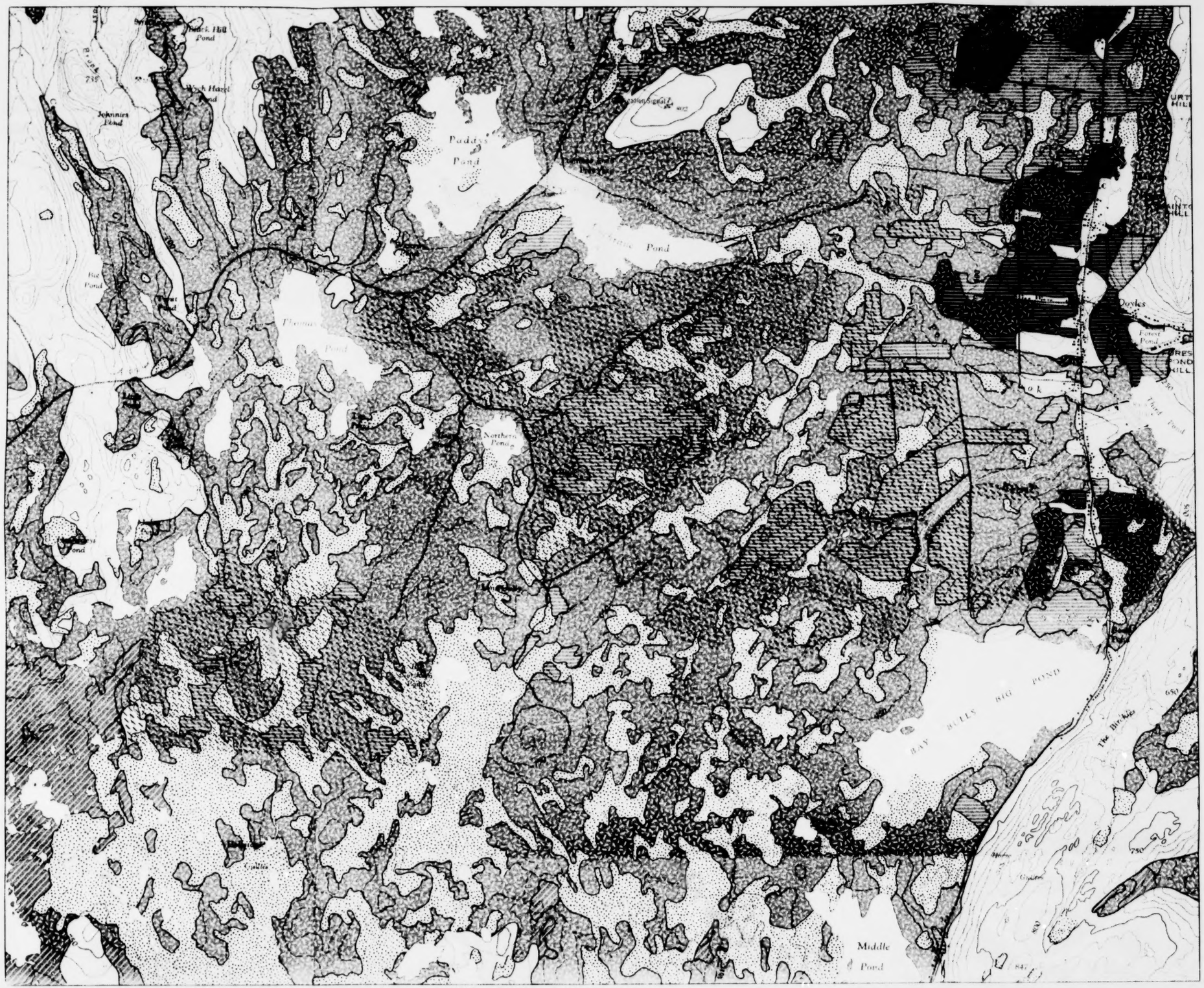

LAND FOR SALIX ENERGY PLANTATIONS

CLASS 1: Areas with slight or no soil and topographic limitations and no land use restrictions.

CLASS 2: Areas with moderate soil and topographic limitations and no land use restrictions.

VEGETATION SUBCLASSES
- Cleared Farmland
- Low Productive Woodland
- Heathland

CLASS 3: Areas with severe soil and topographic limitations and/or land use restrictions.

PEATLANDS: Includes bog, marsh, swamp, fen and organic complexes.

Land requiring revision of lease conditions to accommodate energy farming.

Scale 1:50,000

1000 0 1000 2000 3000

Metres

CONTOUR INTERVAL 50 FEET

Base map from SURVEYS AND MAPPING BRANCH, DEPARTMENT OF ENERGY, MINES AND RESOURCES
Map IN/7

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Map 6: Location of buildings for fuel consumption study

Map 7: Location of Willow Specimens